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ABSTRACT

Some of the investigations concerned with the effectiveness of different modes of responding to programed and computer-assisted instruction (CAI) are reviewed. The findings suggest that when student familiarity with program content is low, or when there is little program redundancy as determined by the blackout ratio, constructing responses leads to higher achievement. Problems with the use of the blackout ratio are discussed. Finally, it is suggested that the greater effectiveness of constructing responses in some cases may be a function of the fact that students are forced to attend to the instructional material for longer periods of time than in other response modes. (Author)

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TECH MEMO

REVIEW OF THE RESPONSE MODE ISSUE

Sigmund Tobias

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This paper reviews some of the investigations concerned with the effectiveness of different modes of responding to programmed and computer-assisted instruction. The findings suggest that when student familiarity with program content is low, or when there is little program redundancy as determined by the blackout ratio, constructing responses leads to higher achievement. Problems with the use of the blackout ratio are discussed. Finally, it is suggested that the greater effectiveness of constructing responses in some cases may be a function of the fact that students are forced to attend to the instructional material for longer periods of time than in other response modes.

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REVIEW OF THE RESPONSE MODE ISSUE

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ABSTRACT

This paper reviews some of the investigations concerned with the effectiveness of different modes of responding to programmed and computer-assisted instruction. The findings suggest that when student familiarity with program content is low, or when there is little program redundancy as determined by the blackout ratio, constructing responses leads to higher achievement. Problems with the use of the blackout ratio are discussed. Finally, it is suggested that the greater effectiveness of constructing responses in some cases may be a function of the fact that students are forced to attend to the instructional material for longer periods of time than in other response modes.

REVIEW OF THE RESPONSE MODE ISSUE[1]

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One of the major ways in which programmed instructional material differs from other instructional resources is the fact that students are required to respond actively to the program. Depending upon the particular program, students may respond by constructing their answer, by picking from a number of available alternatives, or by some combination of these. In addition to the fact that overt responding is a distinctive feature of programmed instruction (PI), making overt responses is of obvious importance to the learning principles on which linear modes of PIs are based (Skinner, 1950). It is, thus, no accident that the importance of making overt responses to PI was one of the first issues to be widely studied by a number of investigators. This area of research has become identified as the response mode issue, and it is the purpose of this paper to review some of these studies, discuss the formulations advanced to explain the discrepant research findings, and suggest several hypotheses regarding the importance of overt responding arising from recent research.

Research Findings

Investigations in which the response mode issue has been studied are conducted with research designs such as the following: A program is administered to one group of subjects in the standard fashion; for other groups the response component of each frame is altered in one of a number of ways. In one variation, the required response blank is filled in creating a series of frames which the subjects are required to read without making any overt responses. This mode has come to be known as the reading format. In a different variation of this procedure, subjects are asked to

"think" the answer required by a particular frame without overtly making response; this has come to be known as "covert responding." Another mode employed in research is to alter a program requiring constructed response (CR) to a multiple-choice format, and comparing that to the CR mode. What subjects learn as a result of the program by the various response modes is than ascertained by posttest.

In view of both the practical and theoretical importance of overt responding to PI, it was somewhat embarrassing to find that making overt responses resulted in no discernable difference with respect to achievement. Anderson (1967) cited nine different studies dealing with response mode, and indicated that a "typical finding" of most of these investigations was no significant difference among a number of response modes.

Proponents of programmed instruction turned their attention to one factor which could account for these unexpected findings: The poor quality of the programs employed in the response mode investigations. The studies reviewed by Anderson (1967) typically occurred in a college environment over relatively short periods of time. Programs were thus employed which were not as carefully developed as they might have been. These considerations led to the development of a measure by which the adequacy of a program could be evaluated: the blackout ratio.

In a number of papers by Holland (1967), Holland and Kemp (1965), and Kemp and Holland (1966), the "blackout ratio" was introduced as a measure of the adequacy of an instructional program. The blackout ratio consists simply of the proportion of words in the program's frames that can be eliminated, or blacked out, without changing the program's error rate. Clearly, this is a useful measure of the amount of redundancy in a program; or, as Holland maintains, the degree to which material is

actually programmed, i.e., the degree to which responses are contingent upon material introduced in a frame. If a student can get the right answer to a frame without inspecting a large proportion of its content, the text of the frame is, obviously, irrelevant to the response it requires. If a program employed in a response mode investigation has high blackout ratios, it would not be surprising if studies based on these programs revealed no differences attributable to response mode, since making the response would then be unrelated to learning the materials in the frame.

Kemp and Holland (1966) blacked out the first 50 frames of 12 programs utilized in different studies pertaining to the response mode issue. The results indicated that programs with the lowest blackout ratios (ranging from 11.1% to 25.4%) had been used in studies with findings in which CR led to superior achievement. On the other hand, studies using eight other programs with high blackout ratios, ranging from 31% to 74.6%, had all found no difference between CR and other response modes. These results suggested that the failure to find differences in those investigations could be attributed to the high blackout ratios of the programs employed.

At about the time Holland and his colleagues were turning their attention to the blackout ratio, other investigators had focused on the importance of the content covered by a program with respect to the response mode issue. Cummings and Goldstein (1964) studied the effects of CR as compared to covert responding to a program dealing with technical aspects of the diagnosis of heart disease. The program required subjects to construct ECG tracings of different types of damage to the heart, and also

dealt with a variety of technical concepts from the area of heart disease. They predicted that overt responding should result in superior achievement on the ECG tracings, though not on the text material. As predicted, highly significant differences in favor of the CR groups were found for the pictorial material; but, contrary to prediction, the differences for the verbal materials dealing with heart disease were also significant, though of lower magnitude. The differences between the response modes were attributed to the technical nature of the subject matter covered by the program.

In three studies Williams (1963, 1965, 1966) found general support for the superiority of the CR mode. The first study (1963) demonstrated that CR and multiple-choice response groups achieved more than two groups who read the program with or without emphasis provided by underlining. On technical or novel items introduced by the program, the CR group achieved more than the multiple-choice group, though not on items involving familiar vocabulary. In the second study, Williams (1965) confirmed these findings with a different program and sample. In the latter study, it was also found that differences in response mode were manifested only on a CR criterion test, and not on multiple-choice items.

Other studies have also found evidence that program content modified the effectiveness of different response modes. Tuel and Metfessel (1965) found overt responding more effective for the mastery of very difficult material as measured by an immediate recall test. The difference, however, disappeared on delayed recall. A program pairing foreign and English words was employed in this study. A suggestion that difficult material was more effectively learned by CR was also found in Goldbeck and Campbell's (1962) data.

The studies reviewed above tended to show that CR led to superior achievement on technical and difficult subject matter. It was suggested (Tobias, 1969a) that the superiority of CR in these studies could be attributed to the fact that subjects had little prior experience with the content of technical and/or difficult programs. On the other hand, programs in which no differences between response mode had been found may well have been covering subject matter with which students were previously familiar. This formulation was tested by a study in which a program covering both technical content unfamiliar to subjects and material with which students had substantial prior experience was developed. Both sets of content were drawn from the same domain, the area of heart disease. The familiar portion of the program consisted of 55 frames and dealt with the following material: (a) The definition of what constituted heart disease; (b) the prevalence and incidence of heart disease; (c) the role of various risk factors, such as smoking, age, tension, and cholesterol, in modifying the probability of contracting heart disease. The most technical terms employed in this program were cholesterol, the difference between incidence and prevalence, and blockage. In conception, this program dealt with material the average undergraduate had been exposed to in the media, though perhaps not with the specificity and detail covered by the program.

The technical portion of the program consisted of a revision of the program employed by Cummings and Goldstein (1964) and dealt with the diagnosis of miocardial infarction originally developed by Francis Mechner (undated). In this program medical terminology for different degrees of severity of coronary disease was used; electrocardiographic tracings characteristic of each level of severity, and graphic representations of

the damage to the heart muscle caused by the various levels of coronary disease were included in this part of the program. The technical section consisted of 89 frames requiring a total of 233 responses. The mean pretest score for the familiar program was 32%. During tryout of the technical portion of the program subjects typically left the test forms blank. For these reasons further pretest scores for this section of the programs were not obtained. The complete program and posttest are reproduced in the final report of the investigation (Tobias, 1968).

A number of studies with these materials (Tobias, 1969a, 1969b; Tobias & Abramson, 1971) have consistently found that the CR group achieved more on the unfamiliar section of the program. Equally consistent was the finding that on the familiar section of the program there were no significant differences between response modes. In a further investigation (Tobias, 1972a) it was also found that scrambling frame sequence did not reduce achievement on the familiar material though on the technical material the scrambled group achieved significantly less, a finding significant beyond the .001 level and accounting for 32% of the variance. These studies strongly suggested that familiarity might well be an important variable in modifying the effects of response mode to PI.

A number of other findings in the literature are also in accord with the familiarity formulation. Karis, Gilbert,and Kent (1968) employed a technical program also dealing with medical subject matter and found that CR led to significantly superior achievement. When synonyms for technical names were scored as acceptable answers, and responses could be paraphrased in nontechnical language, the superiority of the constructed response mode disappeared. These findings suggested that as students could

bring their prior learning to bear on the task, i.e., when the task relied more on previously learned material, there were no differences between different response modes.

Daniel and Murdoch's (1968) study also supports a familiarity interpretation. These investigators found that a group studying Holland and Skinner's (1961) program on operant psychology achieved more than a group studying the same subject matter using Skinner's nonprogrammed writings. The difference was based on a multi-variate analysis of variance using six different indices of achievement as dependent measures. When one subtest which measured knowledge of specific content in the area of operant psychology was eliminated from the dependent measures by covariance adjustment, the difference between the groups on the other measures was no longer significant. These results suggested that the overall group difference hinged on the specific content subtest. It could be inferred that it was this subtest requiring operant terminology with which the subjects had the least experience prior to taking the program.

Roderick and Anderson (1968) found that the achievement of high school seniors on the same Holland and Skinner program was superior to that of a group reading the same material summarized in textbook-like passages. However, for a group of college sophmores, juniors, and seniors enrolled in an educational psychology course, there were no achievement differences between the groups. It seems likely that the college students had a greater familiarity with the concept of operant psychology than did the high school students, especially since general psychology is typically a prerequisite for most educational psychology courses. These findings can thus be considered in support of the familiarity formulation.

The only results directly at variance with the familiarity interpretation were those reported by Entwisle, Huggins, and Phelps (1968). These investigators used a brief program on FORTRAN with a group of undergraduate engineering students, and found no achievement differences between a CR and reading group. Similar findings, for another sample, were also reported for instructional materials dealing with linear systems and design. The nature of this instructional material is described by the authors as "including questions with answers provided a page or two hence, out of the student's view. Before a question is posed, enough text material is given so the question can be answered (p. 405)." It is not clear whether this latter material is a program in the PI sense.

It is difficult to interpret the significance of the Entwisle et al. findings. The FORTRAN program was quite brief, and no data regarding students familiarity with this subject matter are presented. The experiment required both groups to study the material for 20 minutes. Students completing the material were encouraged to reread it until the time limit was exhausted. The same procedure was also followed for the instructional material on linear programming, in which both treatment groups were required to spend three hours working on the program. Since the CR mode usually takes about twice as much time as the reading mode, it appears likely that the subjects reading the material could go over it twice as often as the CR group. These results raise some important questions regarding the efficiency of the CR mode with respect to time; this will be discussed later.

Familiarity data for the FORTRAN material is not reported by Entwisle, et al., though the level of prior familiarity, as determined by pretest, was used as a variable in their second study. This study indicated that

there was an interaction between previous familiarity and response mode such that constructing responses appeared to be more beneficial to subjects with high pretest scores. These findings are opposite to those expected from the familiarity interpretation. Presumably the fact that subjects were required to go over the material for a preset time period affected these results as well.

Knowledge of Results

Response mode studies typically confound two variables: the overtness of response, and the provision of feedback regarding the correctness of the answer made. In the typical response mode experiment the CR group receives knowledge of the correctness of their responses (KCR) in addition to making an overt response. A comparison between CR and a reading group thus, involves more than one variable. Anderson, Kulhavy, and Andre (1971) review a number of studies in a PI context which reported no achievement difference due to KCR. These investigators suspected that the major reason for these results was that, despite instructions not to, subjects frequently peeked at the correct answer in advance of making their own response. An experiment was conducted in which some subjects were unable to peek ahead at the answer, while others were able to do so, and found that the group who could peek learned significantly less from the program, though they made significantly fewer program errors. The error data suggests decisively that subjects did in fact look at the answers, even though they were informed not to, and the achievement data indicate that this peeking ahead did impair achievement from the program. In the two studies reported by Anderson et al. (1971) a no-KCR group learned significantly less than a number of groups receiving different variations of the feedback

procedure. In these studies the investigators employed the heart disease program[2] described previously (Tobias, 1969). In another investigation using this program (Tobias & Abramson, 1971) no achievement differences were found between the group receiving no feedback, and either the feedback group, or a reading group; however, the CR plus feedback group did achieve more than the reading group. In the latter investigations the CR subjects could have peeked ahead to obtain the correct answer but the no-feedback group could not, since the feedback portion of the program booklet had been deleted. Conceivably, the fact that the no-feedback group was able to turn back to prior frames in the Tobias and Abramson investigation, and was not able to do so in the study by Anderson et al., may have affected these results. While no data on the incidence of subjects rereading prior frames were collected, casual observation indicated that subjects did turn back, and in effect provided their own KCR.

It seems clear that PI is not the best medium for the study of CR. There is a substantial amount of implicit confirmation for subject's answers present in most well-designed programs. This implicit confirmation may often make overtly supplied CR superfluous; and, hence, it is not surprising that few PI studies report achievement differences attributable to the KCR variable. If it is desired to eliminate the effects of reinforcement altogether, one way of accomplishing that would be to better scramble the item sequence and at the same time eliminate KCR. In that event the implicit reinforcement present in the program continuity would be reduced, as would the presence of overt KCR. While such a comparison might be of theoretical interest, it would obviously have little implication for practical applications of PI.

CAI Studies

In the contrast to PI response mode, studies have not been very prominent in CAI. Presumably one reason for this lack of popularity is the fact that unless students respond overtly to CAI, it is hard to justify the expense of a computer for cranking out materials which could have been cheaply produced by the mimeograph machine. Thus, most CAI programs demand overt responses, though not necessarily CR. A number of studies pertinent to this issue were conducted using the heart disease instructional materials described above (Tobias, 1972b). In a series of attempts to replicate the PI findings, the program was prepared for CAI in a form identical to the PI format. Since the original program called for extensive graphic, or pictorial, responses in which subjects drew ECG tracings characteristic of different types of heart diesase, and graphic representations of the type and extent of damage to the heart muscles, these procedures had to be changed for CAI presentation. Subjects were presented with a xeroxed handout in which each of the elements of different ECG tracings had been broken down into a series of discrete shapes. Each shape in turn was associated with a particular number. When a student had to make a drawing on the CAI system, he typed in the number representing a particular shape. The shape then appeared on the cathode ray screen of the CAI system. With the exception of this modification, the CAI materials were identical to the materials used in PI research (Tobias, 1968). The first two studies using these materials in the CAI version (Leherissey, O'Neil, & Hansen, 1971; Leherissey, O'Neil, Heinrich, & Hansen, 1971) failed to replicate the PI findings regarding the superiority of the constructed response mode. A task analysis of the CAI version indicated that on

the program subjects were taught to coordinate ECG shapes with numbers; yet on the posttest they are required to actually draw these. In a subsequent study Leherissey (1971) asked subjects to respond on the posttest with the numbers which they had used to construct tracings while working on the program, rather than actually drawing them. Leherissey's findings with respect to response mode replicated those previously reported in PI. Another set of modifications were made to the CAI program in order to replicate PI findings more closely. Two recently completed investigations have demonstrated that the CR mode results in significantly superior achievement (Tobias, 1972b) compared to reading the program, and that a scrambled version presented via CAI resulted in significantly poorer achievement on the technical material compared to the logically-sequenced version (Tobias & Duchastel, 1972).

CR, Familiarity, and Blackout Ratio

Theoretically, it is reasonable to assume that content with which subjects have had extensive prior experience may require a more overt response for optimal learning than does familiar subject matter. Lack of familiarity, or novelty implies that the responses required by the program are not in the student's repertoire. Therefore, actually making the response required may be the best way of mastering it. On the other hand, for familiar subject matter, the required responses may already be in the subject's repertoire, though perhaps not in the exact context required by the material, and thus overt responding may not be as important with this kind of material. On tasks with which the student has had substantial prior experience he does not have to learn how to make the response, but rather how to connect an existing response to new or different content. Overtly making a response which is already learned may not

strengthen its association to new situations to any measurable degree more than covert responding or reading the material. This formulation suggests that for content on which the required responses have been previously learned, little achievement difference may be expected between CR and other response modes. When the response required by a program, however, is new, actually making the response and receiving knowledge of results concerning it is likely to facilitate achievement.

There appears to be a somewhat complex relationship between the familiarity interpretation and the blackout ratio. The familiarity interpretation was generated from research using the heart disease instructional materials. The original version of the technical portion of that program was determined to have had a blackout ratio of 11.1% - 15% by Holland and his colleagues (Holland, 1967). Two attempts were made to ascertain the blackout ratio of the familiar material yielding an initial blackout ratio of 13% and a ration of 24% for this material. It is, therefore, possible to attribute the results of these studies using the heart disease material to the blackout ratio. Since the blackout ratio for the technical material ranged between 11% and 15%, and that of the familiar material was finally established to be 24%, the data could be interpreted as indicating that the lower the blackout ratio, the more likely was CR to lead to superior achievement. On the other hand, Holland and Skinner's (1961) program had a blackout ratio of approximately 25% and still yielded higher achievement. The familiarity studies can, thus, not be considered any direct refutation of the blackout position; however they do raise some questions regarding the usefulness of the blackout ratio.

Blackout studies use the first 50 frames of the program to ascertain the ratio of words which could be omitted. In the first section of any program, the objective is to relate the program's content to materials with which the students are already familiar. Inevitably, thus, this section of any program has the highest blackout ratio, because the programmer here intends to relate the familiar to the unfamiliar. Second, it is difficult to think of any program having blackout ratios much lower than around 20% or so. Typically, removing prepositions, adverbs, adjectives, and some dependent clauses from any program will save anywhere from 15-20% of the words. Humorous asides, literary allusions, and examples which lighten the drabness of some programmed materials raise the word count of a program and can also be considered superfluous in terms of the blackout ratio, but are clearly desirable in terms of maintaining some rapport with the students studying the materials.

Due to some of these considerations, it appears that a formulation which attributes the discrepancies in response mode studies to familiarity, rather than to blackout ratio has both practical and theoretical attractiveness. The theoretical advantage of such a notion is based on the fact that prior familiarity is easily assessed by detailed pretests, and manipulated by experimental pre-familiarization, making it a variable easily employed in research. Should the familiarity hypothesis receive continued experimental verification, the possibility would be raised of employing it as a variable in assignment of pupil to optimal instructional mode. Present results lead to a hypothesis that low prior familiarity with an area would require assignment of a pupil to a constructed response mode for optimal achievement. Pupils with substantial prior experience,

on the other hand, could be assigned to faster instructional modes, such as reading, without any sacrifice in the predicted achievement. Use of this variable for such purposes would, of course, imply that it can be fruitfully employed in aptitude, or attribute treatment investigations (Cronbach & Snow, 1969; Tobias, 1970).

Most of the investigations on which the familiarity hypothesis is based have employed similar instructional materials: the heart disease program. In order for these findings to have any generality it is imperative that this variable be investigated with other instructional programs and instructional modes. Finally, it should be pointed out that familiarity is essentially a different way of looking at an old problem in educational research: the problem of transfer from prior situations to present learning; and as such has a number of knotty problems on its own.

Time

One of the difficult issues concerning the effectiveness of different response modes has to do with the efficiency of modes with respect to time. Most response mode studies have found that CR takes at least twice the time compared to other response modes. Clearly, any program requiring overt response and feedback would require more study time than just reading the program. The question of whether the increased achievement sometimes seen by the use of CR justifies the expenditure of this extra time is one that is difficult to deal with. However, as suggested in Carroll's (1963) model of school learning, all other elements of the model being equal, the greater the student's perseverance, or time spent on a learning task, the greater the degree of learning. In those studies where CR has resulted

in higher achievement, that increment in the amount learned could well have been attributed to the fact that CR required the student to spend more time attending to the learning materials. The question raised here with respect to response mode is similar to that raised by Carver (1970) with respect to the research concerning the effect of embedding questions in prose materials.

The time question suggests that any increased achievement attained by CR may not be due to the overtness of response, the feedback provided, or even the discrete stimulus organization attained by most programs, but instead be attributed to the fact that PI forces the student to spend more time on the subject matter than he otherwise would. The studies by Entwisle et al. (1968), suggest that if subjects using different response modes are required to spend the same amount of time on the material, no achievement differences will result. It seems likely that, given any instructional materials, if subjects are required to spend the same amount of time on them that achievement will not differ greatly. Clearly, subjects could read a program twice in the amount of time required to make CR and receive feedback. It is most unlikely that any study will reveal a difference in favor of CR in such an instance. Heuristically, then, it is conceivable that any instructional method which forces the student to study the material for longer time periods is likely to lead to greater achievement. Since overt response modes fulfill that requirement, one would expect them to lead to superior achievement.

The time question, however, assumes a somewhat different characteristic in the practical instructional context. In a research study, it is not too difficult to ask subjects to reread a program on which they have spent 15 or 20 minutes. Subjects are unlikely to reread the program with the same detail and attentiveness given to it the first time, but they

are likely to read it. On the other hand, are students likely to reread every chapter in a book if they're instructed to do so? Are they likely to reread scrupulously every assignment given? The question being raised here is, even if time is a critical factor in achievement, how can one be sure that subjects will actually spend the extra time going over instructional material? From this point of view, PI and CAI can be seen as avenues which compel the student to spend more time and devote greater attention to the instructional material than he otherwise might. If the expenditure of greater time is accompanied by a high level of interest in the material, low level of fatigue, and if the student in fact does spend the extra time, it would appear clear that these modes have accomplished their purposes.

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FOOTNOTES

1. Presented at the annual convention of the National Society for Programmed Instruction, New Orleans, La., March 1972.
2. A detailed history of the various versions of this program and its uses for research is available in Tobias, 1972b.